DRAFT

70001 – 70006

Deep Drill Core

Frozen samples

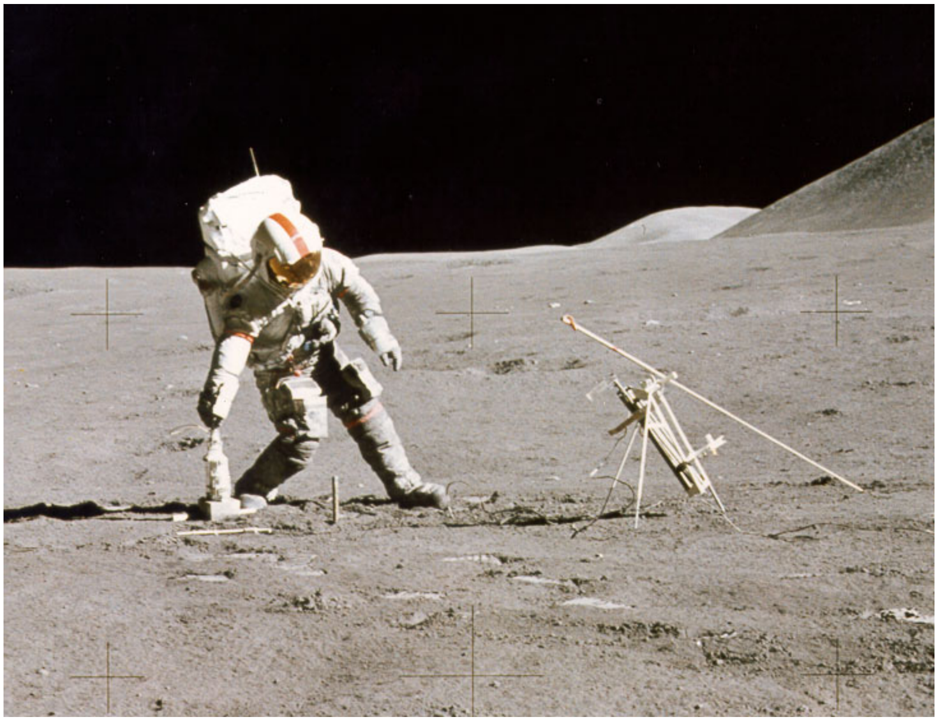


Figure 1: Photo of the Apollo 15 CDR setting up a deep drill. Drilling and extraction on the moon was very difficult and must have caused significant heating. Unless dark drill segments were immediately placed in the shade they would have been sustantially heated. NASA photo AS15-87-11847.

Introduction

The Apollo 17 deep drill (3 meter length) was taken between Camelot and the Central Cluster Craters (figures 1 and 2). Sample 70001 is the bottom-most segment of the drill stem (drill bit); 70009 is the top segment. Portions from the upper ends of 70001, 70002, 70003, 70004, 70005 and 70006 (3 grams each) have been kept in a freezer since 1973 (Table 1) and have never been allocated.

On the moon these samples were at a temperature less than 250 deg. K. (Keihm and Langseth 1973). These six subsamples have been kept at about 250 -260 deg. K since extraction in 1973, although they have been warmed up during drilling and transit from the moon to Houston, and may also have warmed up during brief freezer outages. They were also exposed to spacecraft atmosphere during transit and glove box atmosphere (N2) during sampling. Thus they were at "room temperature" for about 1 month.

The drill string was broken down on the moon into three lengths (figures 4 and 5) and capped on the moon

Table 1: Frozen core samples A17.

sample	weight (g)	depth (cm)	unit (Vaniman)	unit (Taylor)	~ Is/FeO	
70001,5	3.431	290.3 - 292.0	A	H	~40	capped end
70002,5	3.005	251.8 - 252.3	B	H	~55	middle
70003,5	3.004	212.4 - 213.0	C	G	~55	middle
70004,5	2.97	173.2 - 173.7	C	F	~50	capped end
70005,5	3.026	132.7 - 132.3	C	E	~70	middle
70006,5	2.998	94.5 - 95	C	D	~45	capped end

Is/FeO from Morris et al. 1979

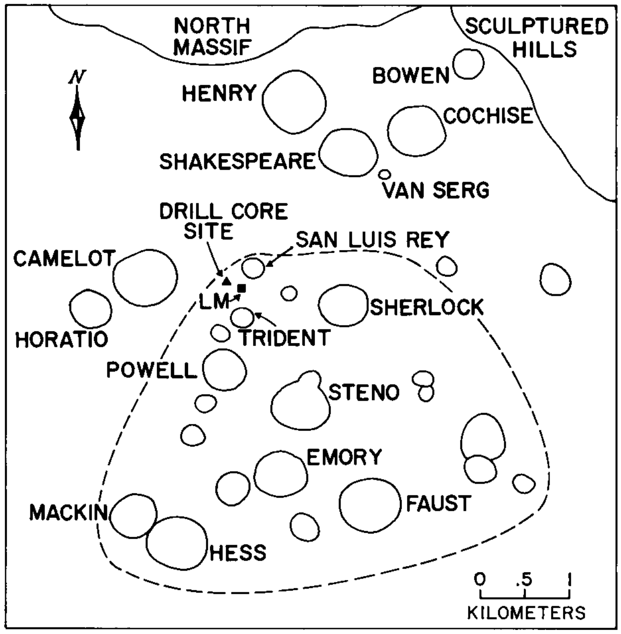


Figure 2: Location of LM, deep drill site and various craters in regolith at the Taurus-Littrow Valley (from Taylor et al. 1979).

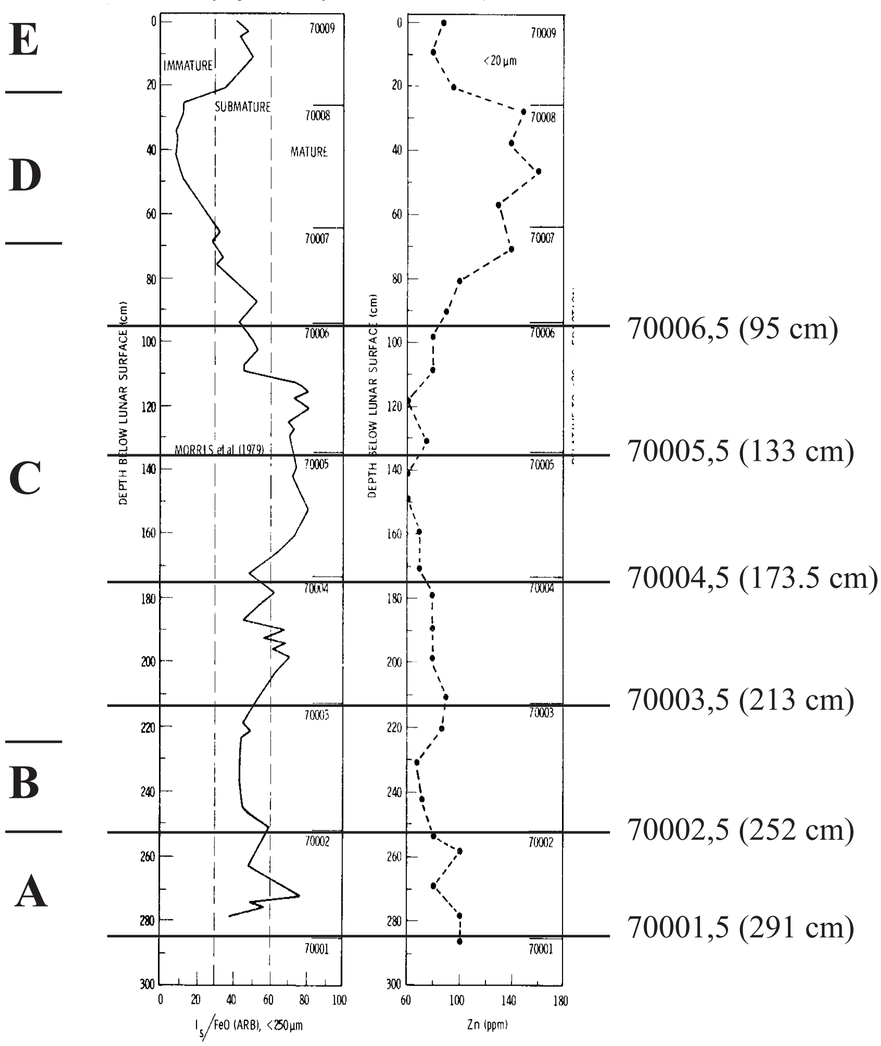


Figure 3: Zn is anticorrelated with maturity in Apollo deep drill string - with approximate location of frozen samples. From Laul and Papike (1980). Petrologic units identified by Vaniman et al. (1979) indicated.

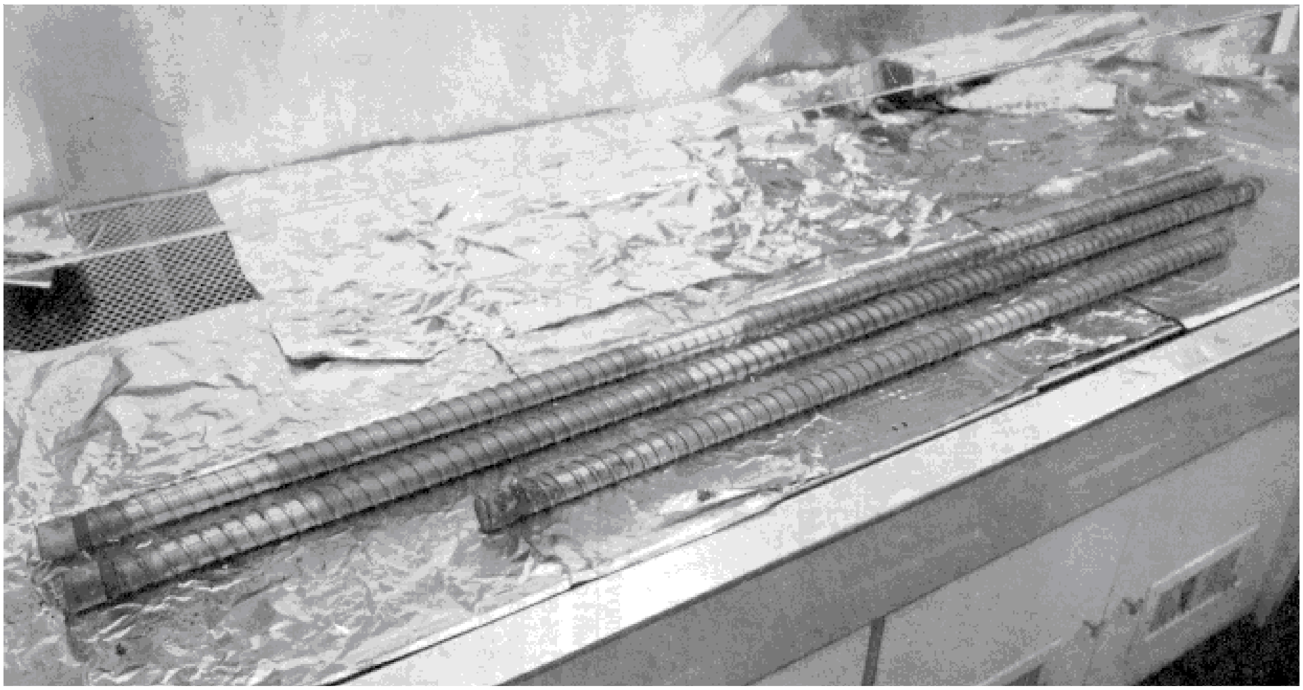


Figure 4: Photo of Apollo 17 drill string as it was brought to Lunar Receiving Laboratory clean bench. Note the ends were capped on the moon. This is figure 13 in Duke and Nagle 1974.

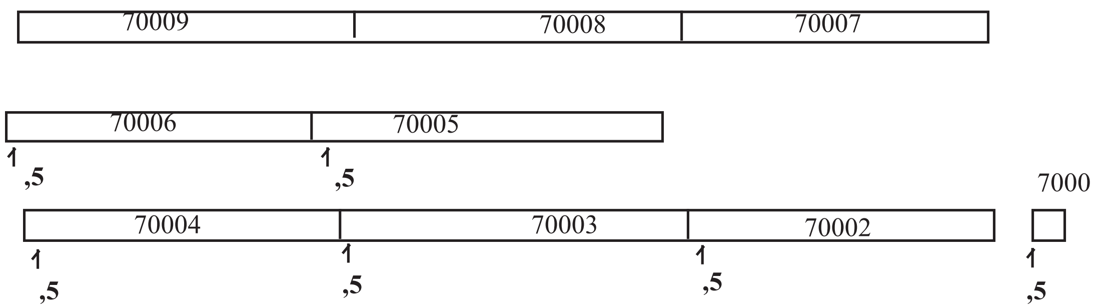


Figure 5: Diagram illustrating that samples 70006,5; 70004,5 and 70001,5 were from capped ends (probably exposed to moisture), while 70005,5; 70003,5 and 70002,5 were from middle of cores tubes (exposed only to nitrogen glove box atmosphere).

(Duke and Nagle 1974). Since they were cycled from vacuum to cabin air several times, the ends must have adsorbed some cabin moisture, but the interior portions should have been well protected (figure 5). The suite of frozen samples (Table 1) were removed from the ends of each segment, under nitrogen, and placed in a freezer (-20 deg C) January 1973.

The capped drill string and bit were returned in a Teflon beta-cloth bag (DSB). Sample 70010 (3.92 grams) is composed of fines inside the bag, and would provide a good control for contamination.

A "reference" soil (70180) was collected about 3 meters from the drill and returned, under vacuum, in ALSRC #1. A 20 gram portion of this sample has also been kept in the freezer since 1973. However, it does not closely match the chemical composition of the lower portion of the drill core (table 2).

The Apollo 17 regolith contains a lot of Zn (~50 ppm) and associated labile elements which Laul and Papike (1980) found anitcorrelated with maturity in the deep drill (figure 3). Note the approximate location of the subsamples that have been kept frozen (top ends each segment).

Petrography

Papike et al. (1982), Laul and Papike (1980) and a comprehensive suite of papers in the Proceeding of the


70001


70002


70003


70004


70005


70006

Figure 6: View of open ends of each drill core section. 70001 is NASA S73-15051, 70002 isS73-15049, 70003 is S73-15046, 70004 isS73-15047, 70005 is S73-15042 and 70006 isS73-15043.

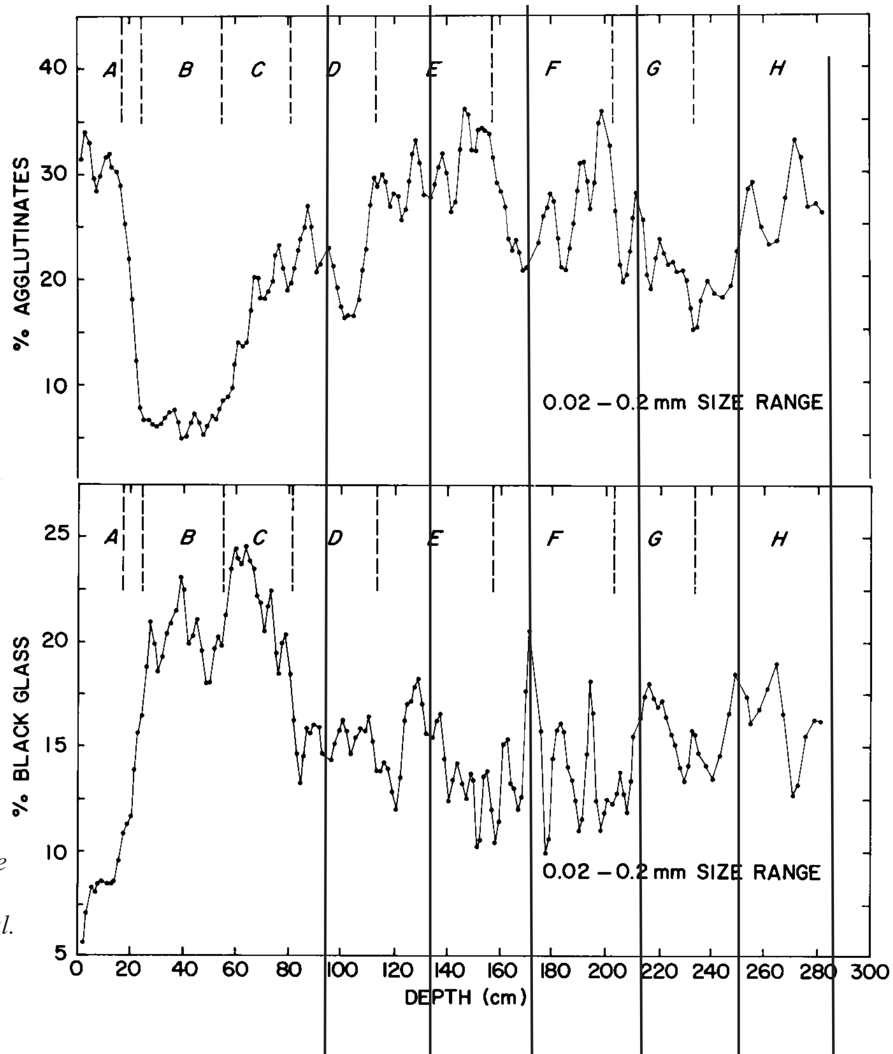


Figure 7: Percentage of agglutinate and of Orange (black) glass along length of drill core (from Taylor et al. 1979). Locations of frozen samples are marked.

10th Lunar and Planetary Science Conference thoroughly describe the full length of the three (3) meter long Apollo 17 deep drill (it has been well studied). Vaniman et al. (1979) tabulated the modal abundance of components for different size ranges, concluding that the Apollo 17 deep drill core was made up of 5 distinct units. "The upper unit E (0-22 cm depth) is marked by high content of fused soil, brown glass, and mare fragments. The underlying unit D (22-71 cm depth) has a low abundance of fused soil (i.e. low maturity) and is rich in coarse (>200 micron) mare fragments. A large section of the core, unit C (71-224 cm depth), is finer-grained, more mature (richer in agglutinates), more feldspathic and has more highland lithic, mineral and glass fragments than unit D. The next underlying unit, B (224-256 cm depth), has yellow/colorless KREEP glasses with a high-Si, low-alkali composition unlike the common Apollo 15 or Apollo 17 KREEP series. The deepest unit, A (256-284 cm depth), is marked by its relatively higher maturity and lower yellow/colorless KREEP glass content". Taylor et al. (1979) see a different set of layers. Morris et al. (1979) have found that the whole lower part of the drill string is mature to submature.

Note: The modal mineralogy of the core is difficult to compare with that of the reference soil sample (70180) because the different investigators use different size fractions, criteria and terminology. Morris et al. found the reference soil (70180) to be submature (although it had high agglutinate content).

Track analysis seems to indicate that the upper one meter, coarse-grained layer of the core was emplaced ~ 10 m.y. ago as a single event (Crozaz et al. 1974). Morris et al. (1979) found this unit to be immature. Nagle (1981) and others (see Papike et al. 1982) have discussed (*at length*) the depositional history of the deep drill core. Finally, Laul et al. (1984) provide a mixing model calculation for the core (figure 10) and

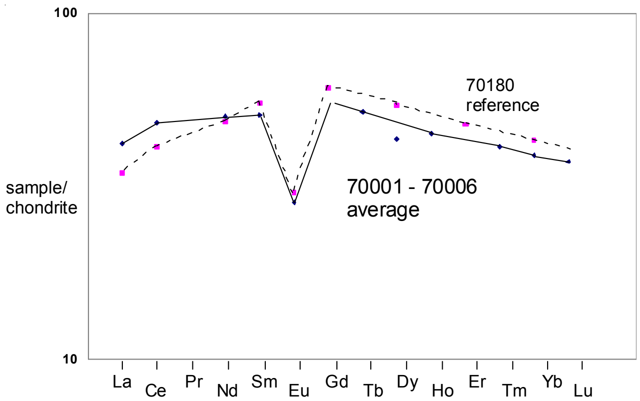


Figure 8: Average of 70001 to 70006 samples compared with rare earth element pattern for reference soil 70180. Data from Table 2.

discovered that segment 70003 contained a high percentage of KREEP in the fine fraction – but not in the agglutinates.

Chemistry

The bottom segments of the Apollo 17 drill string have similar chemical compositions, but are distinctly different from the top segments and the reference soil. They have less Ti, and more K, Ba, U and light REE (Table 2 and figure 8). Laul et al. (1979, 1984) found that portions of segment 70003 had a high percentage of KREEP component, "probably the abundant yellow glass whose origin seems to be exotic". The best evidence for this seems to be elevated Th content.

Laul and Papike (1980) determined the Zn profile for the whole core and found that Zn was anticorrelated with maturity. *At the Apollo 17 site Zn should be correlated with the orange glass content.* Jovanovic and Reed (1974) determined halogens (Cl, Br, I) in the deep drill core (70006, 70005 and 70002) finding less than in the reference soil (70180).

Stoenner et al. (1974) and Pepin et al. (1975) noted that "the H/He atom ratio was higher than the accepted solar wind value by a factor of two" in samples of the deep drill string which they attributed to "water contamination". *However, the H/D ratio has apparently not been studied, and there is always the possibility that the solar wind in the past was different from that today.*

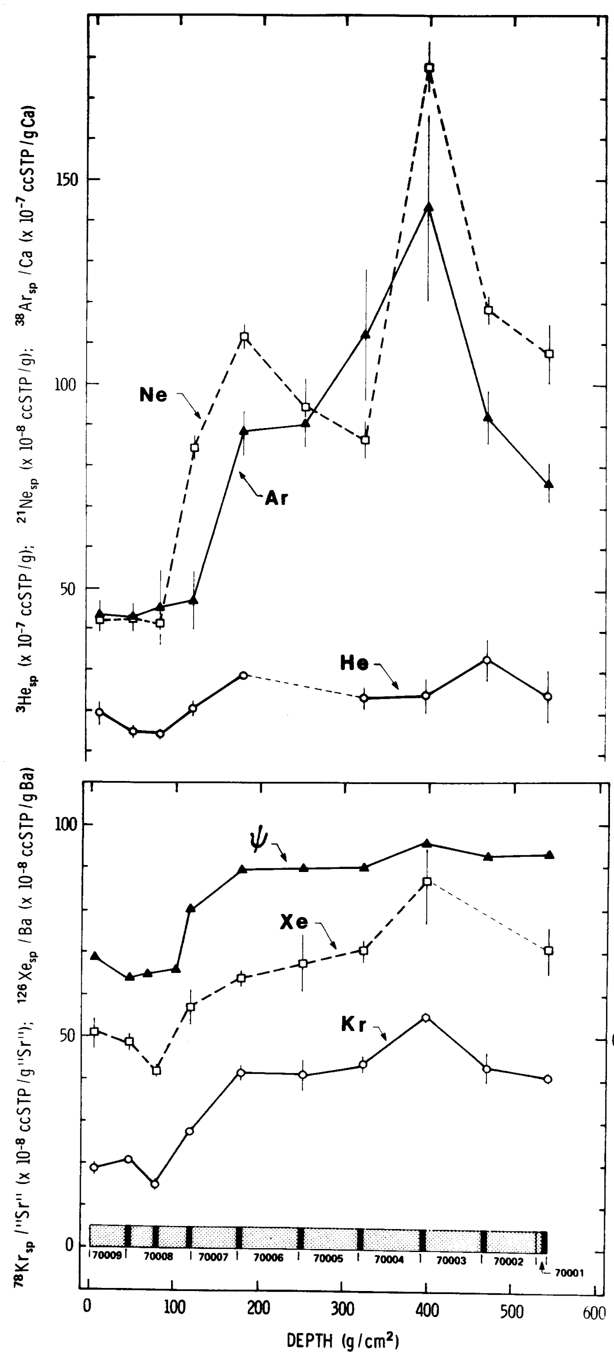


Figure 9: Rare gas content of early end splits of deep drill segments Apollo 17 (from Pepin et al.1975).

Cosmogenic isotopes and exposure ages

Curtis and Wasserburg (1975, 1977), Pepin et al. (1975), Stoenner et al. (1974) and others have studied the results of cosmic ray bombardment of the Apollo 17 drill core. Pepin et al. (1975) found elevated rare gas content at the top of segment 70003 (figure 9). They are not the result of spallation from Ca.

Processing

The frozen core samples have never been allocated, nor studied. In early January 1973, they were scooped from the tops of each core segment in the nitrogen processing cabinets (LRL) used for preliminary examination in (Duke and Nagle 1974), and have remained unopened in their cans (#8) ever since. These cans are stainless steel, with Teflon flip-tops. They are contained inside a sealed 3-liter bolt top can (3 B). *Beware MoS2 grease.*

A precise thermal history for these samples is difficult to construct. Note that the core was briefly exposed to sunlight after extraction – see figure 1 for section on 70180. In any case, the core samples were at "room temperature" from December 11, 1972 till Januray 8, 1973 when the frozen spilts were put in the freezer.

These frozen samples were apparently well protected from a Hg spill (broken thermometer; Jan 1973), because they were in sealed containers within several layers of sealed bags. *However, it will be important to unpackage carefully.*

Additional small splits were scooped from the tops of each segment at the same time (Jan 73) and used for PET. Additional material may have been obtained from core ends before the cores were milled open for dissection.

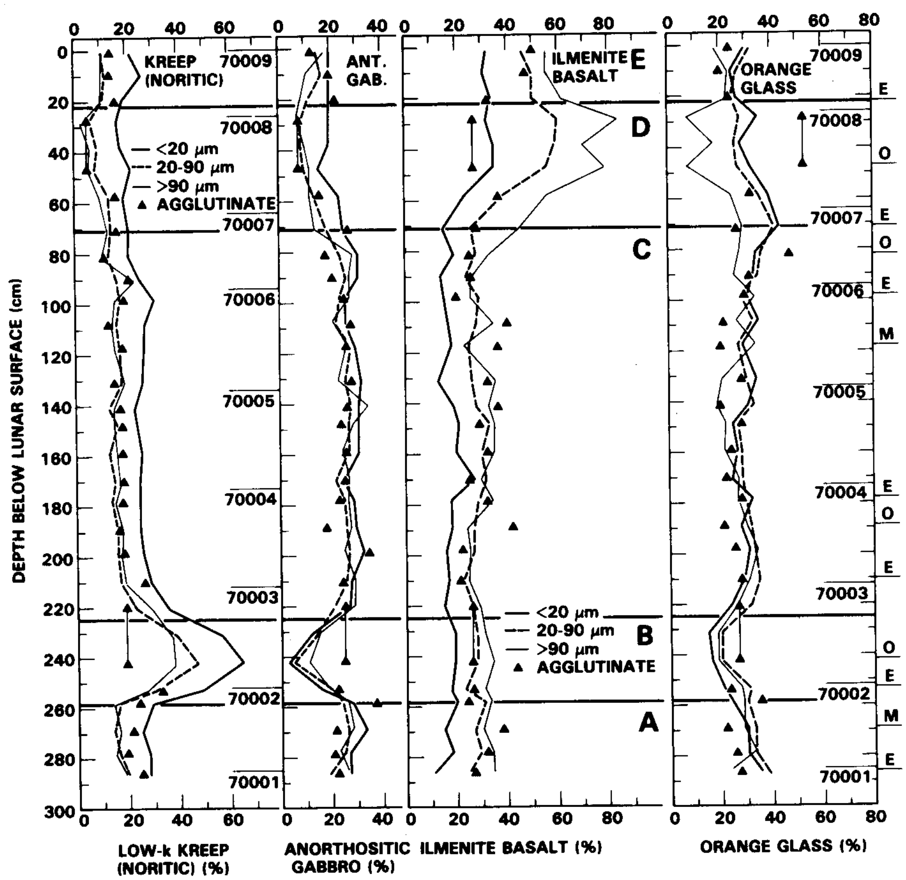
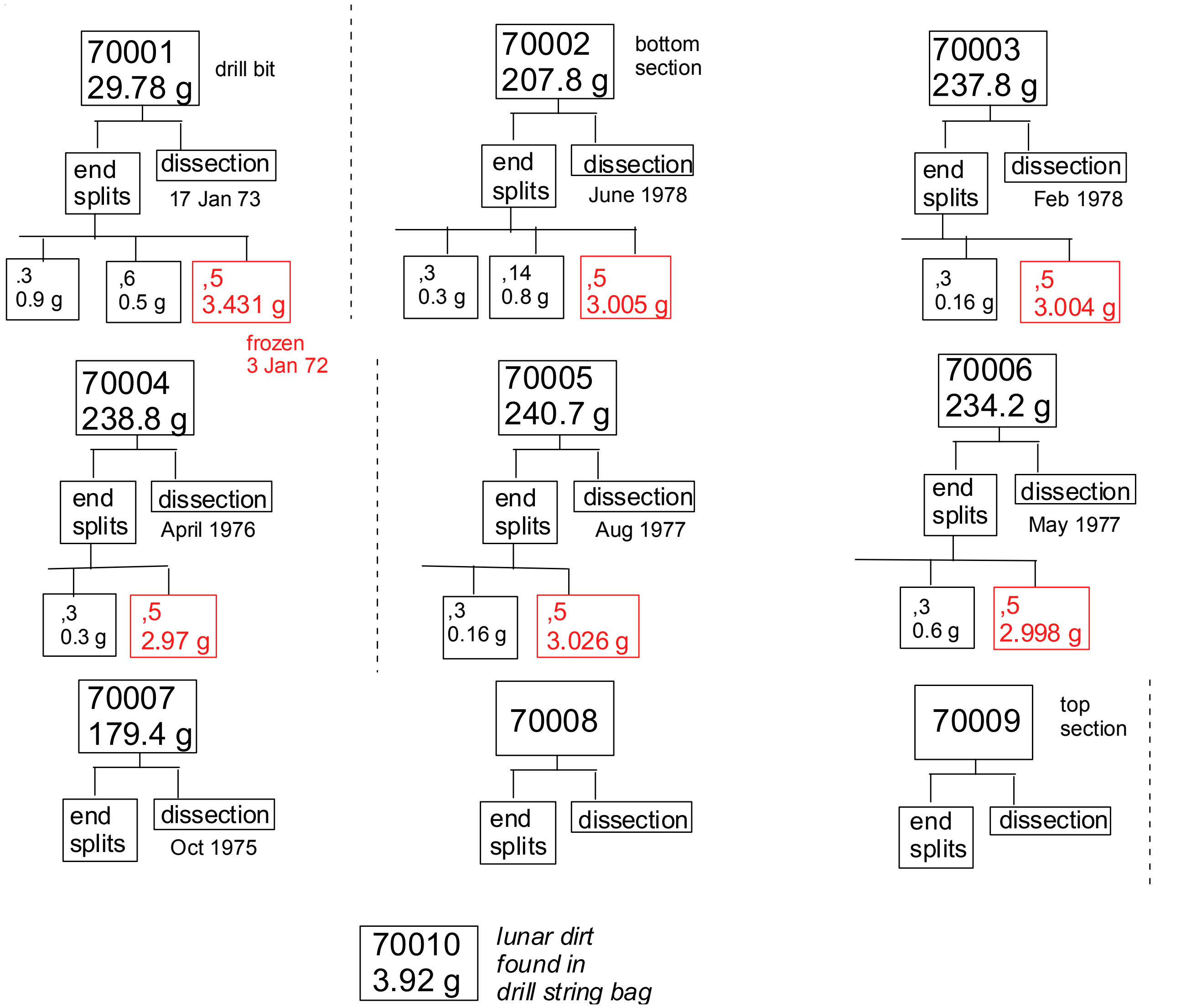


Figure 10: Summary diagram for components found along Apollo 17 deep drill (from Laul et al. 1984). Note that segment 70003 was found to have a high percentage of KREEP(norite) in the fine fraction (but not in the agglutinates).

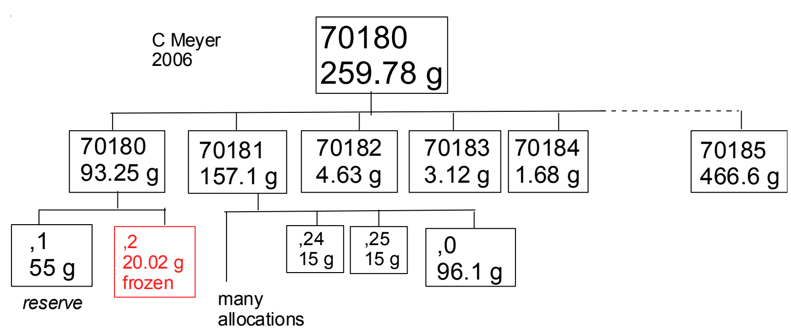
Table 2. Chemical composition of A17 drill core and reference soil.

	70001	70002	70003	70004	70005	70006			70180	
reference	Laul and Papike80		Laul et al. 1979			Laul78		*average(6)*	Rhodes74	
weight	4 mg	15 mg							Wiesmann75	
SiO2 %	42.3	42.3	42.6	42.2	42.1	42.1	(a)	*42.3*	40.9	(b)
TiO2	5.6	5.8	5.7	5.7	5.4	6.1	(a)	*5.7*	8.1	(c)
Al2O3	13.5	14	14.5	13.7	14.4	13	(a)	*13.8*	12.3	(b)
FeO	16	15.4	15.3	16.7	16	16.3	(a)	*16*	16.4	(b)
MnO	0.194	0.19	0.184	0.192	0.194	0.2	(a)	*0.19*	0.24	(b)
MgO	10.5	10.1	10	10.2	9.9	10.1	(a)	*10.1*	9.8	(b)
CaO	11.1	11.2	11	10.5	11.8	10.5	(a)	*11*	11	(b)
Na2O	0.45	0.46	0.44	0.41	0.41	0.43	(a)	*0.43*	0.36	(b)
K2O	0.12	0.12	0.14	0.11	0.11	0.11	(a)	*0.12*	0.085	(c)
P2O5									0.06	(b)
S %									0.11	(b)
sum										
Sc ppm	47.5	47	43.5	51	48.9	50	(a)			
V	80	80	80	85	90	90	(a)			
Cr									2570	(c)
Co	31.3	36	40	44	36.6	36.9	(a)			
Ni	160	210	260	250	250	220	(a)		190	(b)
Cu										
Zn	50	52	47	39	32	40	(a)		47	(b)
Ga	7.4	9	8	7	6.6	6.6	(a)			
Ge ppb										
As										
Se										
Rb									1.5	(c)
Sr	170	170	170	150	170	190	(a)		170	(c)
Y									70	(b)
Zr									340	(c)
Nb									18	(b)
Mo										
Ru										
Rh										
Pd ppb										
Ag ppb										
Cd ppb										
In ppb										
Sn ppb										
Sb ppb										
Te ppb										
Cs ppm										
Ba	130	140	170	120	120	120	(a)	*133*	100	(c)
La	9.5	10	12	9.5	9.23	9.36	(a)	*9.9*	8.1	(c)
Ce	29	30	33	28	27	28	(a)	*29.2*	24.8	(c)
Pr										
Nd	22	23	25	22	22	23	(a)	*22.8*	22	(c)
Sm	7.2	8	7.95	7.33	7.2	7.15	(a)	*7.5*	8.1	(c)
Eu	1.6	1.7	1.55	1.5	1.55	1.7	(a)	*1.6*	1.7	(c)
Gd									12	(c)
Tb	1.8	1.9	1.9	1.9	1.8	1.9	(a)	*1.9*		
Dy	10	10.9	10.5	11	10.5	10	(a)	*10.5*	13.2	(c)
Ho	2.5	2.5	2.6	2.6	2.6	2.4	(a)	*2.5*		
Er									7.6	(c)
Tm		1	1	1	0.96		(a)	*1*		
Yb	6.1	6.7	6.4	6.25	6.21	6.1	(a)	*6.3*	7	(c)
Lu	0.9	0.97	0.91	0.92	0.88	0.9	(a)	*0.91*		
Hf	5.7	6.4	6.27	6	6.05	6	(a)			
Ta	1	1	1.1	1.14	1.02	1.05	(a)			
W ppb										
Re ppb										
Os ppb										
Ir ppb	<10	15	13	16	<10	<15	(a)			
Pt ppb										
Au ppb	3	4.4	3.5	2.8	5.2	3	(a)			
Th ppm	1.5	1.4	1.75	1.3	1.3	1.35	(a)			
U ppm	0.5	0.5	0.45	0.4	0.4	0.4	(a)		0.28	(c)

***technique:** (a) INAA, (b) XRF, (c) IDMS*



reference soil



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